Corn Response to Compost and Manure Amendments Combined with No-Till or Plow Tillage

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Abstract

Livestock producers in the United States are increasingly aware of environmental issues associated with production, storage, treatment and utilization of animal wastes. It is well known that fresh and composted manure can be effectively used to sustain corn production. Rarely studied however, is the conversion from mineral to more organic based systems of nutrients under contrasting tillage systems. We conducted a field study where composted and uncomposted cow (*Bos taurus*) manure (C or M) were applied at three different 'loading' rates of 28, 56, and 112 dry Mg ha^{-1} in the first year, followed by three years of maintenance rates of 11 Mg ha^{-1}. Amendments were applied in the autumn to a clay loam Hoytville soil at Hoytville (H), Ohio and in the spring to a silt loam Ravenna soil at Wooster (W) and either immediately plowed down (PT) or left on the surface as part of the no-tillage (NT) treatment. Controls consisted of a no-amendment treatment and a mineral fertilizer-only treatment. Corn stand counts and grain yields were recorded and soil cores analyzed after three (W) or four years (H) years of treatments. Planting immediately after fresh manure application lowered stand counts when NT was used, but this was not always reflected in grain yields. Delaying planting by a month, or manure incorporation or composting reversed the detrimental effects of fresh manure on seedling emergence. Carbon and other plant nutrient (N, P, K) concentrations were generally significantly greater for the surface soil layers of NT than PT, but the reverse was true at depth. We conclude that high loading rates of manure and composts, followed by annual maintenance rates, are effective in maintaining high corn grain yields. However, care must be taken to first compost the manure or to apply it with incorporation if seeding is immediately conducted.

Project Design

Experimental design

First year amendments were comprised of either low, medium or high initial rates of compost (C) or manure (M) followed by a yearly maintenance rate of approximately 11 Mg ha^{-1} (Table 1). Controls consisted of a 'nothing added' series (F0) and a 'mineral fertilizer-only' series (F1). Amendment treatments were randomized within a rep but tillage treatments, either no-till (NT) or plow till (PT), occurred on one designated side of the plots in order to facilitate the movement of field equipment. Plots measured 9 x 16.5 m at Wooster with 12 rows of corn and 4 reps, and 12 x 15 m at Hoytville with 16 rows of corn and 3 reps.

Table 1. Amount of compost and manure applied, equivalent amount of Total N (in parentheses), and C:N ratio (in dark red).

Timeline	Rate	WOOSTER Compost	WOOSTER Manure	HOYTVILLE Compost	HOYTVILLE Manure
		Mg ha^{-1}			
Year 1 (1998)	Low	28.2 (0.72) 15.5	28.0 (0.65) 13.8	27.4 (0.69) 12.1	43.2 (0.67) 22.4
	Med	56.0 (1.43) 15.5	56.0 (1.30) 13.8	53.5 (1.35) 12.1	85.5 (1.33) 22.4
	High	112 .0 (2.87) 15.5	112.0 (2.60) 13.8	107.5 (2.71) 12.1	170.2 (2.65) 22.4
Year 2 (1999)	One rate	11.0 (0.30) 12.6	9.8 (0.25) 16.3	18.4 (0.44) 14.2	20.6 (0.61) 11.9
Year 3 (2000)	One rate	11.2 (0.31) 9.1	11.2 (0.24) 18.2	7.1 (0.24) 11.3	15.5 (0.26) 17.3
Year 4 (2001)	One rate	15.2 (0.27) 16.2	13.1 (0.34) 14.8	12.7 (0.43) 12.5	10.2 (0.23) 17.6
Year 5 (2002)	None[1]	0	0	0	0
Total for all years	Low	65.6 (1.61)	62.1 (1.48)	65.6 (1.81)	89.5 (1.78)
	Med	93.4 (2.32)	90.1 (2.12)	91.7 (2.47)	131.8 (2.44)
	High	149.4 (3.76)	146.1 (3.42)	145.7 (3.83)	216.5 (3.76)

[1] Residual year, no organic amendments were applied.

Soil cores

Soil cores were taken and analyzed at the beginning of the project before amendments were added, in year 2 (0-20cm cores only), and in years 3 (Wooster) and 4 (Hoytville) (full profile increments). Analyses was done in the STAR Laboratory (http://www.oardc.ohio-state.edu/starlab/).

Organic amendments

Manure came from steers (*Bos taurus*) bedded on wheat straw. At Wooster, the source was a nearby loafing barn and at Hoytville, it was hauled from a privately owned calf replacement facility in the area. Compost for both sites came from the Wooster OARDC compost facility and was, for the most part, a mixture of cow manure and wheat straw bedding. Laboratory analyses of compost and manure were done on samples collected on the day of field application. Estimates of total mineral contribution (Table 2) were based on the amount of amendment applied (Mg ha^{-1}) and the laboratory results.

Table 2. Summary of total amounts of major nutrients added to the soil via organic and inorganic amendments[1].

WOOSTER

Trt.	Available Nitrogen C/M[2]	F[3]	Total	Phosphorous C/M	F	Total	Potassium C/M	F	Total	Calcium C/M	F	Total	Magnesium C/M	F	Total
	kg ha^{-1}														
F0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F1	0	828	828	0	100	100	0	270	270	0	2690	2690	0	490	490
C1	566	619	1185	380	90	470	1090	210	1300	1960	2690	4650	380	490	870
C2	801	367	1168	490	70	560	1570	210	1780	2910	2690	5600	570	490	1060
C3	1266	237	1503	710	60	770	2520	210	2730	4810	2690	7500	960	490	1450
M1	607	675	1282	250	90	340	1520	210	1730	710	2690	3400	370	490	860
M2	897	448	1345	420	70	490	2330	210	2540	1160	2690	3850	680	490	1170
M3	1477	371	1847	750	60	810	3950	210	4160	2060	2690	4750	1300	490	1790

HOYTVILLE

Trt.	Available Nitrogen C/M	F	Total	Phosphorous C/M	F	Total	Potassium C/M	F	Total	Calcium C/M	F	Total	Magnesium C/M	F	Total
	kg ha^{-1}														
F0	0	168	168	0	0	0	0	0	0	0	0	0	0	0	0
F1	0	1246	1246	0	60	60	0	75	75	0	565	565	0	325	325
C1	734	732	1466	720	40	760	2160	75	2240	2660	565	3230	470	325	800
C2	1018	504	1522	1000	40	1040	3020	75	3100	3680	565	4250	640	325	970
C3	1604	416	2020	1570	40	1610	4810	75	4890	5810	565	6380	980	325	1310
M1	723	792	1515	460	40	500	2690	75	2770	2300	565	2870	980	325	1310
M2	1018	559	1577	710	40	750	3870	75	3950	2890	565	3460	1150	325	1480
M3	1607	452	2059	1220	40	1260	6240	75	6320	4070	565	4640	1490	325	1820

[1] Totals are for the first 3 years at Wooster and the first 4 years at Hoytville so that soil cores taken in Spring 2001 and Fall 2002, respectively, can be compared.
[2] C/M = compost or manure amendment
[3] F = mineral fertilizer

Project Design cont.

Mineral fertilizers

Lime, based on soil test values, was applied the first year only at a rate of 12.3 Mg ha^{-1} at Wooster and 2.7 Mg ha^{-1} at Hoytville. Control F0 plots did not receive any lime. Phosphorous (P) and potassium (K) were applied before plow-down each year. First and third year amounts were based on soil core analysis and crop fertilization recommendations from the Ohio 12th Edition Agronomy Guide Bulletin (1988) or the Tri-State Fertilizer Recommendations for Corn, Soybeans, Wheat and Alfalfa Bulletin (1995). For the other years, P and K crop needs were estimated. Nitrogen (N) was applied as ammonium nitrate at both sites in the spring of each year before seeding. Rates were based on a sliding scale to help equalize the difference in N released from the compost or manure (Ohio Livestock Manure & Wastewater Management Guide, 1992).

Weed control

Appropriate herbicides were applied at labeled rates based on the emerged weed community and field history. Translocated herbicides (e.g. glyphosate +/- dicamba) were used usually before crop planting to kill existing vegetation, and residual soil-applied herbicides were used before crop emergence. Weeds escaping these management efforts were controlled with selective post-emergence herbicides as needed.

Corn Varieties

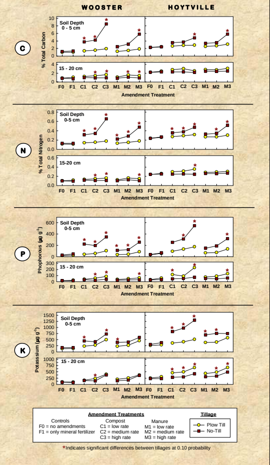
No single type was used at either location but varieties ranged from value-added types such as DeKalb Roundup Ready 566 and Pioneer Bt hybrid 34H32 to a non value-added Bird B54A, which was used two years to determine disease resistance to rust (*Puccinia sorghi*). Seeding rates ranged from 74,000 to 86,000 per hectare with higher rates for the non-value added varieties.

Weather Factors

Precipitation for all years except 1998 at Wooster and 2003 at Hoytville was below normal average for the growing season (June, July and August). Severe drought conditions in year 2002 were reflected in corn grain yields.

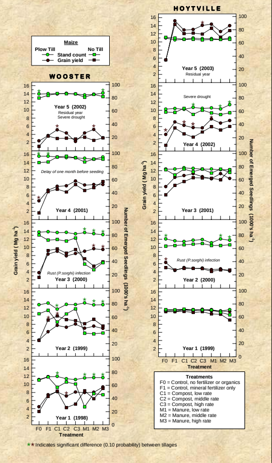
Results

Figure 1. Changes in soil characteristics



*Indicates significant differences between tillages at 0.10 probability

Figure 2. Corn Stand Counts and Grain Yields



** Indicates significant difference (0.10 probability) between tillages

Results, cont.

Total Carbon and Nitrogen, Phosphorous and Potassium

In the 0-5 cm soil depth, NT led to higher total C, N, P and K values compared to PT, especially when compost and manure were applied at high rates (Figure 1). Total C values for this top layer of soil for NT exceeded 8% for compost and 5% for manure at Wooster and 5% to 6% at Hoytville. Such high C levels can be expected to greatly impact the soil physical, chemical and biological properties. Percent total N values for NT averaged 0.57 at Wooster and 0.50 at Hoytville with slightly higher values for compost than manure. In general, C/M amendments led to higher NO_3 levels than the mineral fertilizer (F1) treatment at both sites.

In the 15-20 cm depth, PT soil had relatively more total C, total N, P and K than NT due to inversion of the surface layer during tillage operations. Concentrations, however, were far less than those in the top layer for NT. Total C values for PT soil at the 15-20 depth averaged only 1.5% at Wooster and 2.75% at Hoytville. Total N values for C/M PT treatments averaged 0.15% at Wooster and 0.31% at Hoytville.

Soil pH, Bulk Density and Other Plant Nutrients

Soil pH at the 0-5 cm layer was not significantly affected by tillage except for the control-plus-fertilizer (F1) treatment where NT exhibited lower pH than PT most likely due to a concentration of acid produced in this soil layer under NT. Addition of C/M (pH values of amendments ranged from 7.1 to 9.1), significantly raised soil pH from 6.7 to 7.2 at Wooster and from 6.1 to 7.0 at Hoytville. At lower soil depths, PT led to higher pH than NT due to inversion of the surface layer during tillage operations.

Bulk density in the 0-5 cm layer of soil decreased with NT when compared to PT at the Wooster site, especially when compost was applied, but increased at the 10-15 cm depth for most of the C/M treatments. Tillage effects at Hoytville were only significant for the highest rate of C/M with decreased bulk density for NT when manure was added.

Soil Ca levels increased significantly when C/M was added at Wooster, but not at Hoytville, probably due to the initial higher rate of Ca in this soil (i.e. 3000 $\mu g\ g^{-1}$ compared to 1000 $\mu g\ g^{-1}$ at Wooster). NT led to higher amounts in the 0-5 cm depth at Wooster when compared to PT, but the same effect did not occur at Hoytville. PT soils at Wooster usually had higher Ca levels in the lower depths, but this effect was also not noticed at Hoytville.

Mg levels in the 0-5 cm depth increased significantly with all C/M additions at Hoytville, but only with the higher rates of C/M at Wooster. NT resulted in significantly more Mg in the 0-5 cm layer compared to PT, with concentrations ranging from 550 to1100 $\mu g\ g^{-1}$ for high C/M rates at Wooster and an average of 660 for C/M treatments at Hoytville. Mg levels in the lower depths were slightly elevated for PT with concentrations in the 250 $\mu g\ g^{-1}$ range at Wooster and the 500 $\mu g\ g^{-1}$ range at Hoytville.

Corn Stand Counts and Grain Yields

Stand counts at Wooster decreased when manure was used along with NT and seeding immediately followed amendment application (Figure 2). In Year 4 at Wooster, when weather conditions delayed seeding for one month, stand counts on manure plots did *not* significantly differ between NT and PT. At Hoytville, two out of the four years showed lower stand counts on manure treated plots when NT was used even though the manure was fall-applied. At both sites though, decreased stand counts did not result in comparable grain yield decreases. Corn grain yields were often less for NT than PT, even though the opposite result is generally observed at the Wooster site. This was attributed to weed pressures that were not well controlled causing severe competition, especially for water during the drought years.

Challenges of Field Research with Organic Amendments

- Composts and manures are not homogeneous materials, resulting in the need for larger analytical sample sizes and increased number of subsamples.
- Moisture is not consistent throughout the storage pile and can change with weather conditions, leading to differences between estimated and actual amounts applied to the soil.
- Weighing of unwieldy organic materials to attain precise application rates is difficult and time consuming.
- Field application using large equipment, such as manure spreaders, can lead to uneven coverage necessitating hand labor.
- Windy conditions can transport dried compost across or from the field.
- Sloped fields can lead to movement of amendments to adjacent plots.

References

- Ohio Livestock Manure & Wastewater Management Guide, Bulletin 604. 1992. The Ohio State University.
- Ohio 12th Edition Agronomy Guide, Bulletin 472. 1988. Ohio Cooperative Extension Service.
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Conclusions

Manure, both fresh and composted, can be used to improve soil quality by increasing soil pH and carbon levels, lowering bulk density, and adding N, P, K, Ca and Mg for plant uptake. But, if fresh manure is applied and no tillage is practiced, seedling emergence rates could be negatively affected. Therefore, planting should be delayed until decomposition has occurred or the manure should be composted before applying to the field. Plow-down of fresh manure can lead to improved stand counts, but it also lowers carbon sequestration potential and decreases nutrient levels in the upper layer of the soil where germination occurs.

Decreased corn stand counts did not necessarily result in lower grain yields if initial seeding rates were high enough.

The benefits of the initial, one-time high application rate extended to subsequent years and were continued by using a much lower annual maintenance rate of application.

Funding and Project Support

Support was provided by Fund for Rural America. Thanks to all the field crew who helped with this project and the Shulte Farm for providing us with raw materials. Thanks also to B. Bishop for statistical support.